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DIGITAL SPEED SWITCH MODEL DSS-1

INSTRUCTION MANUAL

Report 87-1-K

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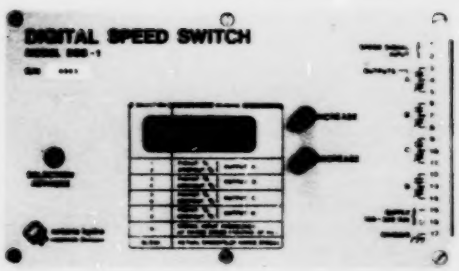

A microprocessor-based digital speed switch has been developed for use with hydraulic generators and for other similar applications where equipment is to be turned on or off for various values of a speed signal. The speed switch provides up to four relay outputs whose contacts open and close at pre-selected speeds. This manual includes a description of both the hardware and software of the device, as well as details on installation, maintenance and principles of operation.

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J.C. Kuurstra

1. INTRODUCTION

The DSS-1 Digital Speed Switch (Figures 1 and 2) is a microprocessor-based control relay to be used with hydraulic generating equipment or in other applications where equipment is to be turned on or off for various values of a speed signal. It replaces mechanical flyball-type speed switches used for enabling or disabling equipment such as oil pumps, brakes, and field excitors. It also has a "creep detection" setting which allows the unit to act as a conventional creep detector. The DSS-1 is designed to be powered from the station battery.

The Speed Switch operates by continuously monitoring the frequency of a signal from a permanent magnetic generator (PMG) or speed sensor. The frequency of the speed signal is compared with four pairs of pickup/dropout setpoints to determine which of four relays should be picked up. The eight setpoints can be individually preset using pushbuttons and a 4-digit LCD display on the front panel. In its normal mode of operation, the DSS-1 continuously displays the actual generator speed as a percent of rated speed.

The DSS-1 is initially calibrated by entering the frequency (in tenths of Hz) of the signal source at rated generator speed. The setpoints are then entered as a percentage of rated speed. The setup procedure is entirely digital (analogous to setting a digital watch) and requires no test equipment. Following the initial setup, the calibration and setpoints are stored indefinitely in non-volatile memory until they are changed by the user. There is no need for periodic adjustment or recalibration. Changing setpoints, or inspecting existing setpoints, can be done at any time, while the DDS-1 is operating.

The DSS-1 accepts input signals from a PMG directly, provided they meet the input requirements given in the specifications (Section 2.1). Other types of speed sensors may require additional interfacing circuitry. A speed sensor interface, described later in the report and shown in Figure 3, has been designed for use with a particular induction proximity sensor (as specified in Section 2.2).

2. SPECIFICATIONS

2.1 DSS-1 Specifications

Power Requirements:	100-300 Vdc (5 W max)
Signal Input:	Any periodic waveform that meets the specified voltage and frequency requirements whose frequency is proportional to speed: for example, one phase voltage from a 3-phase permanent magnet generator (PMG). NOTE: The DSS-1 requires that the power supply be electrically isolated from the input signal. If this is not the case, the input signal must be isolated with a suitable isolating transformer or equivalent. The DSS-1 will also accept a speed signal from an inductive proximity sensor, using an external interface board (see Speed Sensor Interface Specifications).
Signal Input Requirements:	Maximum Voltage: 150 Vrms (no damage) Minimum Voltage: 2.2 Vrms, at all required frequencies of interest. (proper operation)
Input Signal Frequency Range:	0-200 Hz
Input Signal Frequency for Rated Speed:	3.0-99.9 Hz, selectable in 0.1 Hz steps. The signal frequency in Hz, for rated generator speed, is entered using front panel push buttons.
Number of Speed Trip Levels:	Four, corresponding to 4 output relays, each with settable pickup and dropout setpoints. Setpoints are entered using front panel "INCREASE/ DECREASE" pushbuttons. The pickup setpoint is constrained to be at least 2% above the dropout setpoint (ie, if one is being changed, the other is automatically adjusted if necessary to meet this constraint). Range: Pickup: 5-199% in 1% steps plus "creep"* Dropout: 3-197% in 1% steps plus "creep"* (100% = rated generator speed) * See Creep Detection

Creep Detection:	Applicable only when using a speed sensor that works down to dc (such as an inductive proximity detector). Any of the four output relays can be programmed to detect creep. With this setting, at every Hi to Lo input transition (metal to no-metal for the recommended inductive proximity detector) the output relay for that channel will be (or remain) energized for 7 seconds. External relay logic may be used, if desired, to block the creep output when the generator is rotating under normal operation. (See details in Section 5.4).
Storage of Calibration and Setpoint Data:	Non-volatile Random Access Memory
Worst Case Operating Time: (ie, time from when instantaneous speed passes setpoint until the DSS-1 relay picks up or drops out):	Two complete cycles of signal frequency plus 33.3 ms, if frequency is less than 6 Hz. (Note 1) One cycle plus 200 ms, if frequency is greater than or equal to 6 Hz. For example: 1) If the signal frequency is 6 Hz at rated speed, and the pickup setpoint is 20%, the operating time is less than $\frac{2}{0.2 \times 6} + 0.033 = 1.7$ seconds 2) If the signal frequency is 60 Hz at rated speed, and the pickup percent is 80, operating time is less than $\frac{1}{0.8 \times 60} + 0.200 = 0.221$ seconds
Measurement Accuracy:	+/- 0.5% of rated speed
Measurement Resolution: (Setpoints and display)	1% of rated speed. (Readings are rounded to the nearest percent.)

Note 1: The factor '2' is a worst case for all conditions. It can be shown that when the input speed is changing at a constant rate, the worst case operating time is approximately 1.5 cycles plus 35 ms.

Display:

4-digit Liquid Crystal Display. Leftmost digit shows display selection; the three rightmost show the value, as shown in the following table. See also Figure 4.

Selection	Displayed Value
1	Pickup setpoint, output A (%)
2	Dropout setpoint, output A (%)
3	Pickup setpoint, output B (%)
4	Dropout setpoint, output B (%)
5	Pickup setpoint, output C (%)
6	Dropout setpoint, output C (%)
7	Pickup setpoint, output D (%)
8	Dropout setpoint, output D (%)
9	Signal frequency at rated speed (tenths of Hz)
"blank"	actual speed (% of rated speed)

Display Selection:

SELECTION ADVANCE pushhbutton advances display once per push. If no pushbutton pushed for 30 seconds, display selection reverts to selection "blank" (ie, showing the actual generator speed).

Controls:

1. SELECTION ADVANCE pushbutton.
2. INCREASE/DECREASE pushbuttons to adjust the setpoints.

Output:

Four relays, each with 1 Form C contact (rated at 0.25 A, 250 V resistive; 0.1 A 250 V inductive @ L/R = 25 ms).

Effects of Loss of Input:

Output relays, if picked up, will de-energize within 7 seconds after loss of input signal. Relays may de-energize momentarily if the signal is disconnected for less than 7 seconds, corresponding to what appears to the DSS-1 to be a transient drop in speed.

Effects of Loss of Supply Volts:

Any closed contacts will open after t seconds,

where;

t = 2 ms (approx)
for a supply drop from 100 V to 0 V

t = 800 ms (approx)
for a supply drop from 100 V to 50 V

All calibration and setpoint data will be preserved.

Transient Interference Susceptibility:	Withstands 2500 V transient (level B) on every input and output, applied both common mode and differential mode, in accordance with Ontario Hydro Standard A-28M-82. (Note that this specification applies for the DSS-1 itself. When the solid state speed sensor interface is installed, this specification is not applicable for the signal input terminals.)
Radio Frequency Interference (RFI) Susceptibility:	Withstands RFI applied in accordance with Ontario Hydro General Tendering Document C-5047-77 (Walkie-Talkie Test) without damage or interference to the operation of the DSS-1.
Electrical Connection:	Removable screw-clamp terminal strip mounted on outside of box. Accommodates wire sizes up to #14 AWG.
Mechanical:	Metal box designed for wall/panel mount Size: 19 x 11 x 7.4 cm Weight: 1.2 kg
Environmental:	Temperature: 0-55°C Humidity: 10-90%, no condensation

2.2 Speed Sensor Interface Specifications

Power Requirements:	100-300 Vdc, 1.6 W maximum
Signal Input:	Accepts signal from TURCK Model NI5P12Y0 inductive proximity sensor or a Lo signal $\leq$ 0.62 mA and a Hi signal $\geq$ 2.43 mA.
Maximum Frequency:	200 Hz (duration of interface output signal sensing metal present or not present must each be more than 2.0 ms)
Interface Mounting Requirements:	Plugs into the side of the DSS-1, where the screw-clamp terminal strip normally plugs in. The interface provides its own screw-clamp terminal strip, identical in configuration and wiring to the original screw-clamp terminal strip.
Sensor Size:	Length: 30 mm Outside Diameter: 12 mm
Sensor Mounting Requirements:	See Appendix E

3. INSTALLATION AND SETUP

CAUTION

> The DSS-1 requires that the power supply be electrically isolated from the input signal. If this is not the case, the input signal must be isolated with a suitable isolating transformer or equivalent.

The DSS-1 Digital Speed Switch requires a panel space of 19 cm by 11 cm, and a depth of 7.4 cm. Wires are connected to the DSS-1 by means of a removable terminal strip. External connections are shown in Figure 4. If a solid state speed sensor and interface are used, these should be mounted and wired as described in Section 3.3.

The setpoints and rated speed parameters are entered using the front panel pushbuttons. The SELECTION ADVANCE pushbutton is used to select the desired parameter to be displayed. The display selection number is displayed in the leftmost digit of the 4-digit display and the parameter value is displayed in the 3 rightmost digits. If no pushbuttons are pressed for 30 seconds, the display selection automatically reverts to "blank", and the parameter value displayed is the actual generator speed.

A particular parameter can be modified by first selecting the display of the desired parameter and then pushing the INCREASE or DECREASE pushbuttons as required. Momentarily pushing these pushbuttons increments or decrements the parameter by one, whereas holding the button down continuously causes the parameter to increase or decrease rapidly. Following a change, the new value is then stored in non-volatile memory the next time the SELECTION ADVANCE pushbutton is pressed, or after 30 seconds of no button-pushing, whichever comes first.

The operating parameters can be viewed at any time, including when the generator is on line, without affecting the operation of the DSS-1. By pressing the SELECTION ADVANCE pushbutton the required parameter can be displayed. The setpoints can be modified at any time, but any changes will be immediately reflected on the relay outputs. A display test (all 8's) can be performed by first selecting actual speed (selection "blank") and then pushing the INCREASE and DECREASE pushbuttons simultaneously.

3.1 Rated Speed Setup

To set the "rated speed" parameter, it is necessary first to determine the input signal frequency corresponding to rated (ie "100%") speed. Where the signal source is a PMG this information may be obtained from the nameplate data. If a speed sensor is used, the input signal frequency will be the rated shaft speed of the generator in revolutions per second times the number of complete metal-to-nometal-to-metal transitions seen by the sensor for each revolution. For example, if the rated shaft speed of the generator is 120 rpm and the timing wheel sensed by the speed sensor has 36 teeth, then the "rated speed" parameter is 120/60 x 36 = 72 Hz.

To enter the rated speed parameter, the SELECTION ADVANCE pushbutton should be pressed repeatedly until the number "9" appears in the leftmost digit. Then the appropriate INCREASE or DECREASE button should be pressed until the required value in tenths of Hz is displayed. For example, a 72 Hz rated speed signal requires the number "720" to be displayed.

3.2 Setpoint Setup

Display selections 1-8 display the pickup and dropout values for the four output relays. Selections 1,3,5, and 7 display the percent speeds at which the relays pick up, and 2,4,6, and 8 display the percent speeds at which the relays drop out. The INCREASE and DECREASE pushbuttons may be used as required to set the desired values. Note that the DSS-1 requires the pickup speed to be at least 2% above the dropout speed, to provide hysteresis and avoid relay chatter. When the user is changing either setpoint, the DSS-1 will check for this constraint and, if necessary, automatically adjust the other setpoint as required to maintain a 2% pickup-dropout differential.

An output relay can be used to indicate a creep condition by lowering the setpoint until the display shows "EEP". If either the pickup or dropout setpoint is set for creep the other will automatically be set for creep.

3.3 Speed Sensor Installation

The speed sensor interface is a separate circuit board that plugs into the side of the DSS-1, where the removable screw-clamp terminal strip normally plugs in. See Figure 1. The interface provides its own screw-clamp terminal strip, identical in configuration and wiring to the original screw-clamp terminal strip. See Figure 9 for sensor wiring details. Appendix E describes the installation requirements for the inductive proximity sensor.

4. PRINCIPLES OF OPERATION

The DSS-1 operates by continuously monitoring the speed signal input and calculating the speed by measuring the average period between negative-going zero crossings over a measurement period of about 160 ms, or after every negative-going zero crossing, whichever is longer. The average period is converted to a percentage of rated speed of the generator and rounded to the nearest percent. This percent value is compared to the eight speed setpoints stored in non-volatile memory. If the speed is greater than or equal to the pickup setpoint, the relay is energized. If the speed is less than or equal to the dropout setpoint, the relay is de-energized. If the speed is between the two setpoints, the relay status remains unchanged.

As mentioned in the previous paragraph, the measured actual speed is rounded to the nearest 1% of the rated speed. Because of this, the hysteresis is actually 1% less than might be expected from the difference between the pickup and dropout setpoints. For example, a 20% pickup will energize a relay at speeds of 19.5% or higher and similarly a dropout setting of 18% will de-energize the relay at speeds of 18.5% or lower. The actual hysteresis, therefore is 19.5%-18.5% = 1%.

The DSS-1 can be set up to detect creep if the inductive proximity sensor is used. The operation of the creep detector is essentially that of a 7-second retriggerable one-shot. That is, if one or more of the outputs have been set for creep, then at every metal-to-nometal transition the output relay will energize for about seven seconds. When the generator is starting, the output relay will energize at the first metal-to-nometal transition and, provided the acceleration is such that the subsequent metal-to-nonmetal transitions are less than 7 seconds apart, the relay will stay energized. When the generator is at speed, operating normally, the time between transitions will be much less than 7 seconds and the relay will be continuously energized. Similarly, as the generator is brought to a stop the relay will only deenergize when the time between transitions is more than seven seconds. It should therefore be noted that the creep detector output indicates any motion, and does not distinguish between creeping and normal operation. Where such a distinction is required, appropriate external relay logic should be used to block the creep detector output during normal operation of the generator and for a 40-second period after the generator has been brought to a stop. (See also Section 5.4.)

5. CIRCUIT DESCRIPTION

The DSS-1 hardware design is based on a similar previously developed device called the MDI-3: Maximum Demand Indicator/1/. Extensive changes have been made to the input, output and power supply sections, but the microprocessor and display circuitry is essentially the same.

The DSS-1 circuitry is contained on two printed circuit boards connected by a 26-conductor jumper cable. Schematic diagrams for the boards are shown in Figures 5 and 7. The component locations are shown in Figures 6 and 8.

The display board, designated DSS-A, contains the power supply, low voltage detectors, input signal conditioning, relays and drivers and the liquid crystal display. The display board is mounted on the lid of the DSS-1 box. The CPU board, designated DSS-B, contains the microprocessor, crystal, program EPROM, and the non-volatile memory. The CPU board is mounted on the display board with metal spacers. The two circuit boards are electrically connected by a permanently attached 26-conductor jumper cable. The mounting pads for this cable are shown by square boxes on the schematic diagrams.

For applications where a speed sensor is to be used, a separate interface board is mounted externally at the connector. (See Sections 3.3 and 5.4.)

5.1 Power Supply and Relay Driver Circuits

The 100-300 V input supply voltage is zenered down to 10 V through power resistor R35 and zener VR4. The total current consumption of the DSS-1 ranges from approximately 5 mA with a 100 V supply to 13 mA with a 300 V supply. Capacitor C1 provides filtering for the 15 ms high-current (30 mA) pulses required by the NOVRAM (U9). Transient protection is provided by R33, R34, C19, C20 and VR3. A low power regulator, Q1, provides a regulated 5 V for the circuitry. The 100-300 V input voltage is also applied to the output relays. A pair of monostables, U14A and U14B are configured as a 20 kHz pulse-width modulator to drive the MOSFET power transistor to provide an average 24 Vdc to the relay coils. The pulse- width modulator is disabled until the voltage across the zener VR4, is about 8 V as determined by voltage detector U1. Voltage detector U1 also interrupts and resets the microprocessor if the voltage is below 8 V. Voltage detector U2 monitors the regulated +5 V to signal the microcomputer that the supply voltage is within specifications.

5.2 Input Speed Signal Circuitry

A Schmitt-triggered inverter is used as a zero-crossing detector in this circuit. The input to the inverter is biased at 2.5 V by resistor divider R39,R40. Capacitor C22 provides a low impedance path for common mode 60 Hz noise. Resistor R37 limits the current into C22 during high voltage transients. The input signal is filtered by RC combination R36,C21 and then fed to the inverter U5 through current-limiting resistor R4. Resistor R44 grounds the inverter when no signal is connected to the DSS-1. The resultant square wave generated by the inverter is fed into monostable U3B. At every positive-going zero crossing (ie. negative-going zero crossing at the DSS-1 input terminal 1), a 50 μs pulse is generated by the monostable. This train of 50 μs pulses is fed into the interrupt port IRQ of the microprocessor.

The "return" side of the speed signal input is internally connected to the negative side of the power supply through a 100 kΩ resistance (parallel combination of R39 and R40).

5.3 CPU

The DSS-1 is based on a Motorola MC146805E2 8-bit CMOS microprocessor U7. The microprocessor has four input signals, namely the input signal pulse train and 3 pushbutton switches, identified as the SELECTION ADVANCE (S4), INCREASE (S6), and DECREASE (S5). The microprocessor uses four out-

put ports to turn on the four output relays.

Integrated circuit U8 is used to latch the lower eight bits of the address bus. Parts of U11 and U12 are used to decode addresses to provide chip selects for components external to the microprocessor, such as the 4-digit display driver U6, and the NOVRAM U9. The control program is stored in U10, a 4k-byte CMOS EPROM. All temporary and working data is stored in the 112 byte RAM portion of the microprocessor chip U7.

The non-volatile RAM or NOVRAM, U9, provides storage of the calibration and setpoint parameters when power is off. Via transistor switch Q6, the NOVRAM is powered only when required such as when the DSS-1 is first turned on or when parameters are changed.

The hardware watchdog circuit consists of U3A, C5, C6, R6-R9, CR3, CR4, Q3 and two gates from U5. Approximately every 30 ms, the microprocessor will pulse pin 2 of U3, a retriggerable monostable multivibrator. The rising edge of the pulse will cause pin 13 to go high, and then stay high for at least one cycle (30 ms), since the time constant of the multivibrator is greater than that. If the program hangs up, the pulses will not occur, and pin 2 of U3 will stay high or low, thereby causing the multivibrator to time out, making pin 13 go low. The voltage on C6 will then decrease. When it goes below the threshold of U5, the output of U5 will go high and turn on Q3, which will reset the microprocessor and restart the DSS-1 control program.

5.4 Speed Sensor Interface

In addition to accepting speed signals from a permanent magnet generator, the DSS-1 will also accept signals from an inductive proximity sensor. An interface board is required, however, to match the low level signal produced by the sensor to the input requirement of the DSS-1. The interface board described below was specially designed for a TURCK "YO" series inductive proximity sensor. The schematic circuit diagram of the interface is shown in Figure 9 and the component layout is shown in Figure 10.

When connected to the interface input terminals 1 and 2, the proximity sensor is powered from the station battery through a 36 k Ω resistor (R1). In this configuration, the power supply to the sensor is essentially a constant current source varying between 3 mA (100 V battery) and 9 mA (300 V battery). The sensor acts as a variable resistor with a change in impedance between approximately 1 k Ω (no metal sensed) and 20 k Ω (metal sensed). When metal is sensed, the current passed by the sensor is approximately 0.62 mA, and the voltage across R3 is about 2.4 V. When no metal is sensed, the sensor is in a low impedance state and the sensor operates at a position on its V-I curve such that the voltage across R3 and the sensor is 12 V (nominal) plus a diode drop. The voltage across R3 in this state turns out to be about 9.4 volts.

The metal/nometal voltage signal is fed into a Schmitt inverter U1-C to provide buffering and hysteresis. The Schmitt is powered from a 12 V power supply regulated by zener CR6. The output of the inverter is fed to the DSS-1 input on pin B1. The negative-going transitions input to the DSS-1 (ie. metal-to-nometal) are the ones used by the DSS-1 to calculate the period of the input signal.

On occasion, the generator being monitored may come to rest in a position such that the sensor is midway between sensing metal and no metal. Since the input signal level may then be very near a positive transition, noise may eventually cause the Schmitt output to change state. If this happens, the resulting output Hi to Lo transition would be detected by the DSS-1 and could erroneously set off the creep alarm. To prevent this, a 20-second timer comprised of R5,C4 and U1-D is used so that approximately 20 seconds after the absence of pulsing (ie 20 seconds after the generator comes to rest), the input is momentarily pulsed HI via U1-E and CR4, to force the input into a state furthest (from a voltage standpoint) from the Hi to Lo transition used by the DSS-1 for timing. The result of this is that about 20 seconds after a unit comes to rest, there may be a creep output lasting 7 seconds on the outputs that have been set to detect creep. (External relaying should therefore allow for creep outputs to be on for as long as 40 seconds following a normal stop).

6. SOFTWARE DESCRIPTION

This section describes the software used in the DSS-1. To aid in the description, refer to the flowchart given in Figure 11. The software is written in 6805 assembly language. As of the date of issue of the present report, the most recent revision of the software is version 2.1 and the corresponding source code (on file at the Research Division) bears the file designation "DSSV21".

The software is divided into three functional routines: the external interrupt routine, the internal interrupt routine and the main program. The main program executes in the background while the interrupt routines interrupt the main program to perform calculations and service the timer counters. The three routines are described in more detail below.

External Interrupt

This routine is entered whenever an external interrupt is generated. An external interrupt can be generated in one or more of three ways: a negative transition on the input signal, a low voltage condition, or if the watchdog circuit times out. The last two cases are abnormal conditions and cause the software to reset the speedswitch. The first case occurs whenever there is a negative going transition at the signal input circuit. When this occurs, a flag (EXTFL) is set to indicate that an external interrupt has occurred. If a timer interrupt should occur while the external interrupt is being serviced, another flag (TIMFL) is set as well. The actual servicing (ie storing counters etc) of the external interrupt is performed in the internal interrupt routine.

Internal Interrupt (Timer Interrupt)

The frequency of the input signal is determined by measuring the period. A 24-bit counter having a resolution of 5 μs is used for this. The lower eight bits of the counter is a hardware timer, included on the CPU chip, which counts to zero and interrupts the main program every 1.28 ms by means of an internal interrupt. If no external interrupt had occurred since the last timer interrupt, the 24-bit counter is incremented by 256 (ie 1.28 ms). If an external interrupt did occur since the last timer interrupt, the value that the 24-bit counter had at the time of the external interrupt is added to a running total (FREQ). If the total is greater than 8000H (corresponding to 163.9 ms) it is stored and reset to zero. The number of cycles (NUMCY) that have been added to obtain the total is also stored. The total and the number of cycles are used in the main program to calculate speed. The speed calculation, therefore, is based on the lowest integral number of cycles whose total period is greater than 160 ms.

Main Program

The main loop calculates the speed, updates the relay outputs, services the pushbuttons and updates the display. This loop takes about 200 ms to execute.

The speed in percent of rated speed is calculated using the number stored by the timer interrupt routine. The speed is compared to the setpoints associated with each relay output and the outputs are updated accordingly. If any buttons are pushed, appropriate action is taken and then the display is updated.

7. BENCH TEST

A general checkout of the DSS-1 can be performed by connecting an ac signal generator to connections A1 and A2 of the DSS-1 external connector. To test the DSS-1 with the speed sensor interface installed without the speed sensor, connect a 0-12 V variable frequency square wave signal generator between A1 (positive) and A15 of the external connector of the interface.

WARNING:

The power supply to the DSS-1 must be isolated from the output of the signal generator.

8. MAINTENANCE AND TROUBLE-SHOOTING

The DSS-1 has no internal adjustments and does not require periodic maintenance. Since the Speed Switch's time reference is a crystal oscillator, no periodic recalibration is required. In the unlikely event that the data in the non-volatile memory gets corrupted, the DSS-1 will display the word "HELP" on the display. If this should occur, the setpoints and rated speed parameter should be checked and corrected.

Normally, if a DSS-1 mulfunctions, it should be returned to the manufacturer or to a suitably equipped repair centre for servicing. However, for some types of malfunctions, a field repair may be possible, as described in the following paragraphs.

WARNING:

The DSS-1 contains CMOS devices which can be damaged by electrostatic discharge. Service personnel should observe proper handling precautions for CMOS devices.

The first thing to check is the power supply voltage which should be 5.0 +/- 0.3 volts. This voltage can be measured on the power supply pin of any integrated circuit except U9, such as, for example, pin 40 of microprocessor chip U7. If the power supply voltage is within limits, and the symptom indicates the area of the board that is faulty, it may be possible to make repairs by plugging in new integrated circuits. This approach will not work with the program EPROM (U10) because it must first be programmed with the DSS-1 software (currently version 2.1). U10, or any other parts, could be obtained from a DSS-1 that is known to be operating correctly.

To aid in the location and replacement of components, component layouts for each of the boards are shown in Figures 6, 8 and 10 and a parts list is given in Appendices A and C. Following any maintenance work, the applicable parts of the test procedure given in Appendices B and D should be used to verify that the DSS-1 operates correctly.

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REFERENCE

/1/ Bruce, J.D., **Maximum Demand Indicator Model MDI-3 Instruction Manual**, Research Report 85-153-K, September 30, 1985.

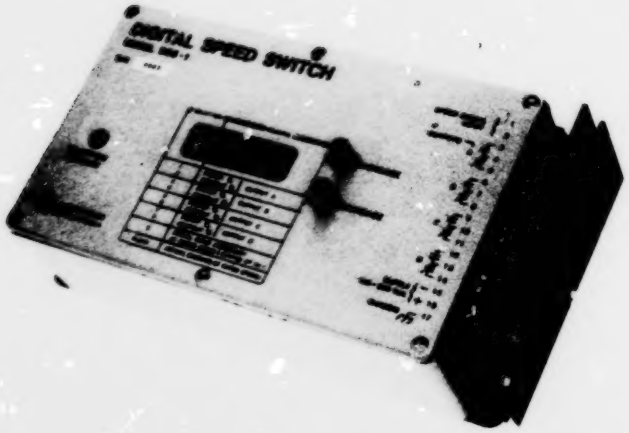

FIGURE 1
DIGITAL SPEED SWITCH MODEL DSS-1
(WITH SPEED SENSOR INTERFACE)

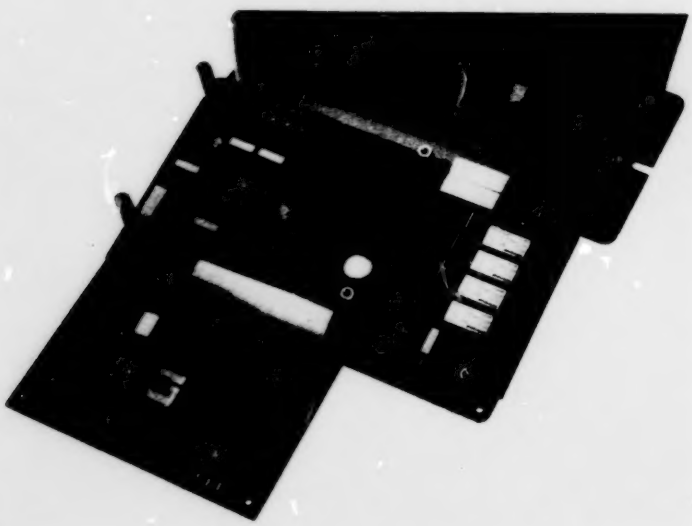

FIGURE 2
DSS-1 INTERIOR VIEW

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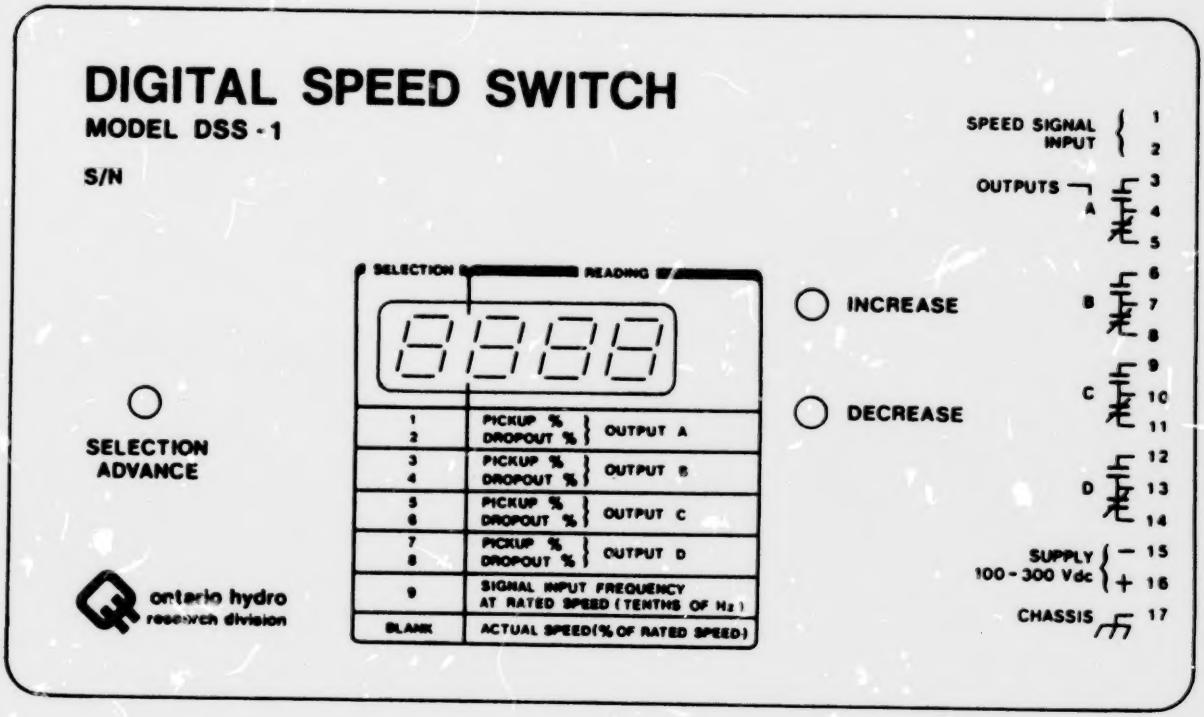
173704-RD

FIGURE 3
SPEED SENSOR INTERFACE AND SENSOR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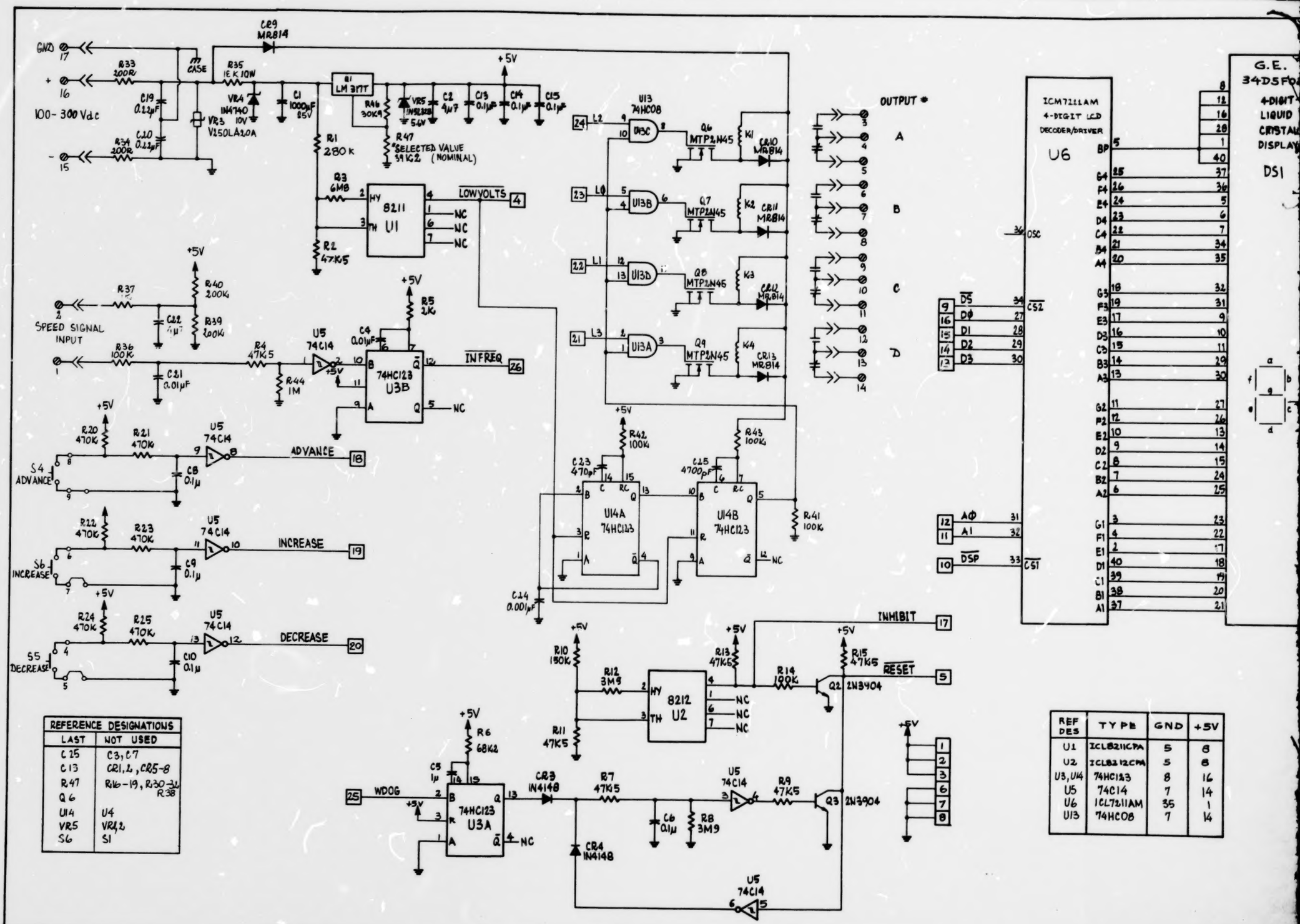
SELECTION
READING
1 2 PICKUP % DROPOUT % OUTPUT A
3 4 PICKUP % DROPOUT % OUTPUT B
5 6 PICKUP % DROPOUT % OUTPUT C
7 8 PICKUP % DROPOUT % OUTPUT D
9 SIGNAL INPUT FREQUENCY AT RATED SPEED (TENTHS OF Hz)
BLANK ACTUAL SPEED(% OF RATED SPEED)
INCREASE
DECREASE
SPEED SIGNAL INPUT 1 2
OUTPUTS A 3 4 5
B 6 7 8
C 9 10 11
D 12 13 14
SUPPLY 100-300 Vdc − 15 + 16
CHASSIS 17

FIGURE 4

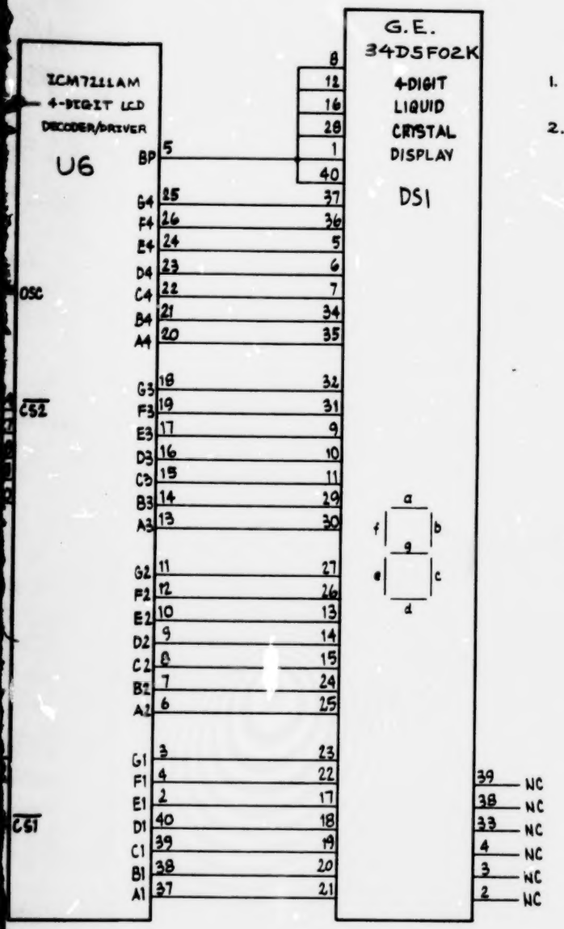
FRONT PANEL LAYOUT OF DSS-1

87-1-K
173418-RD



REFERENCE DESIGNATIONS	
LAST	NOT USED
C25	C3, C7
C13	CR1, 2, CR5-8
R47	R16-19, R30-32, R38
Q6	
U14	U4
VR5	VR1, 2
S6	S1

REF DES	TYPE	GND	+5V
U1	ICL8211CPA	5	8
U2	ICL8212CPA	5	8
U3, U14	74HC123	8	16
U5	74C14	7	14
U6	ICL7211AM	35	1
U13	74HC08	7	14



NOTE

1. □—DESIGNATES PIN NO ON J1
2. ⊘—≪ DESIGNATES SCREW TERMINAL FOR FIELD WIRING

FIGURE 5
DISPLAY BOARD SCHEMATIC

87-1-K

REF DES	TYPE	GND	+5V
U1	ICL8211CPA	5	8
U2	ICL8212CPA	5	8
U3, U14	74HC123	8	16
U5	74C14	7	14
U6	ICM7211AM	35	1
U13	74HC08	7	14

2	23JUL86	R47 VALUE CHANGED, C7 DELETED	TT		
1	86JUL 86	CIRCUIT CHANGED	TT		
no.	date	revisions	drawn	check	ref. no. number

DIGITAL SPEED SWITCH DSS
DISPLAY BOARD SCHEMATIC DSS-A

ontario hydro
research division

drawn: G.GOSTKOWSKI	checked: H. VAN ZANDEN
date	approved
scale	dwg no: 40373 RD R 2

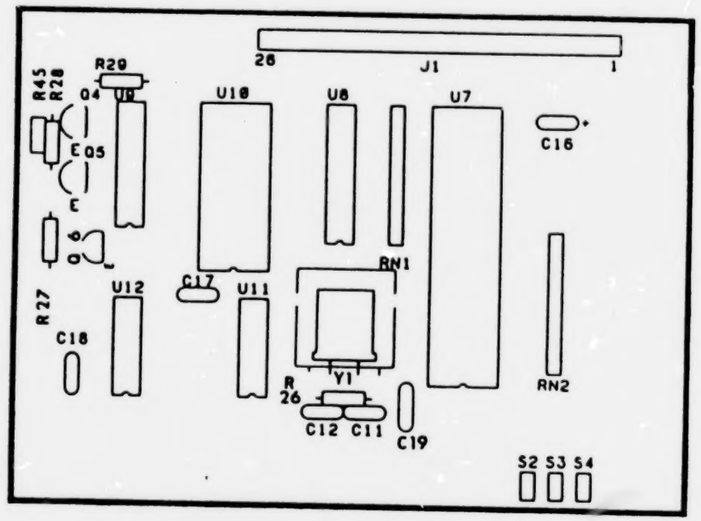
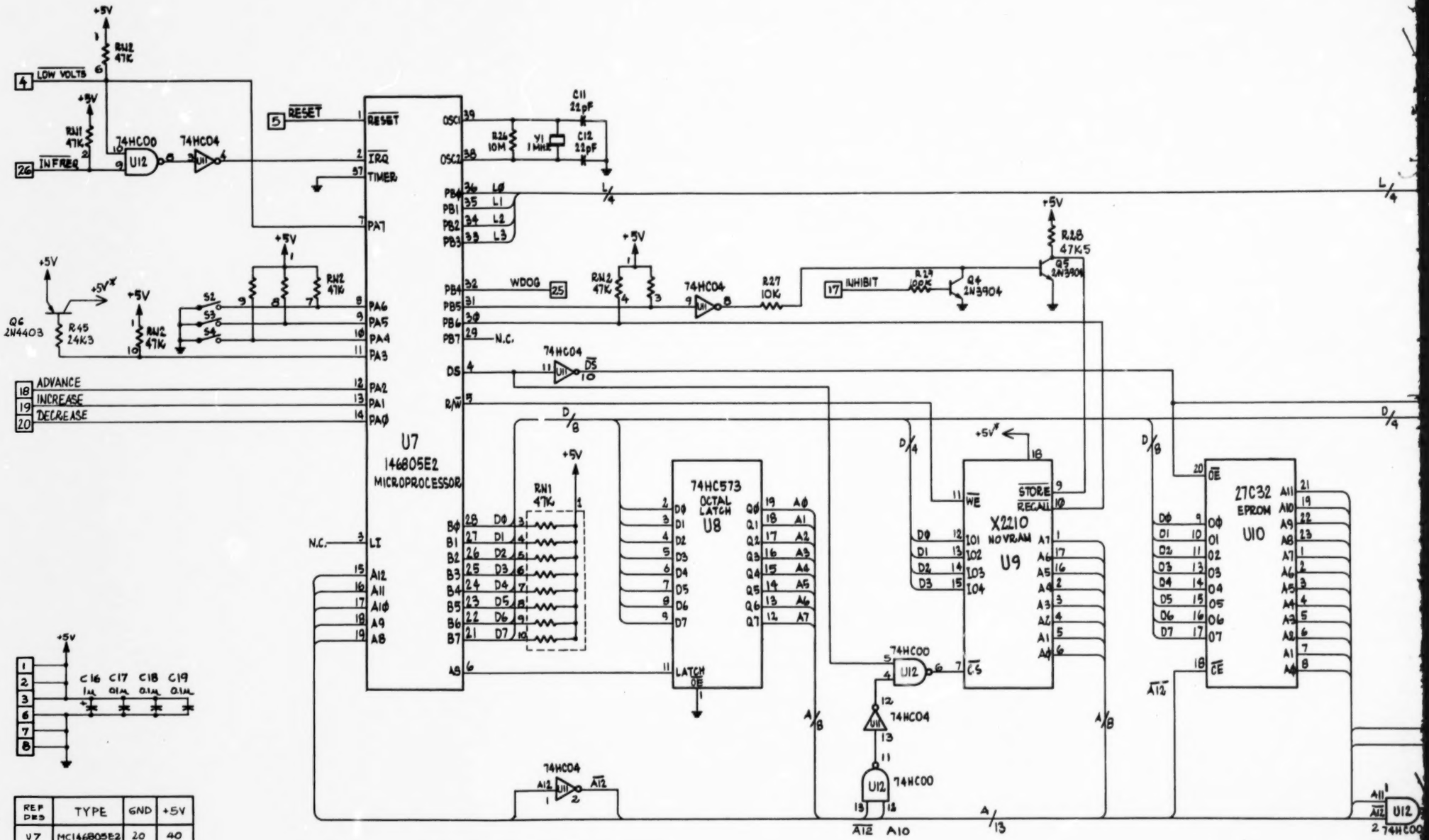


FIGURE 6
DISPLAY BOARD COMPONENT LAYOUT

87-1
173419-RD



REF DES	TYPE	GND	+5V
U7	MC146805E2	20	40
U8	74HC573	10	20
U9	X2210D	8	18*
U10	NMC27C32	12	24
U11	74HC04	7	14
U12	74HC00	7	14
RN1	47K SIP		1
RN2	47K SIP		1

* SWITCHED +5V VIA PA3

NOTE

□ — DESIGNATES PIN NO ON J1

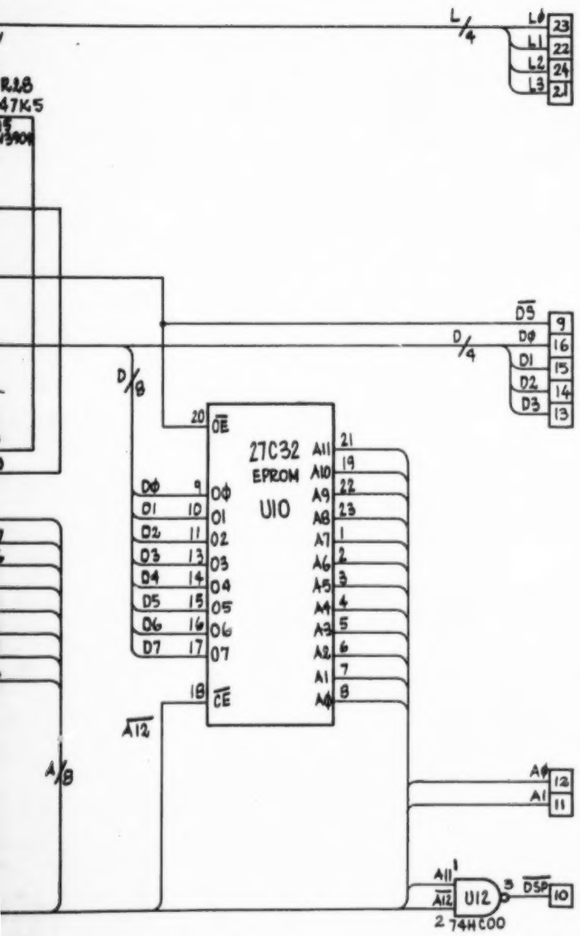


FIGURE 7

CPU BOARD SCHEMATIC

87-1-K

1	8 V [illegible] R19 VALUE CHANGED	99		

DIGITAL SPEED SWITCH
CPU BOARD SCHEMATIC DSS-8

ontario hydro
research division

drawn G.GOSTKOWSKI	checked H. VAN ZANDEN
date	approved
scale	drwg no 40374 RD R1

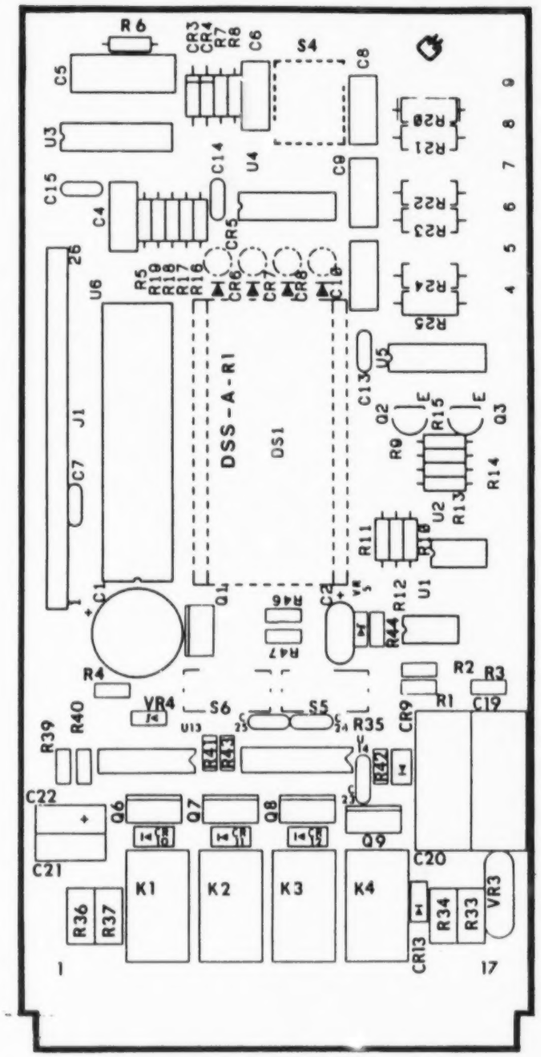


FIGURE 8

CPU BOARD COMPONENT LAYOUT

87-1
173420-RD

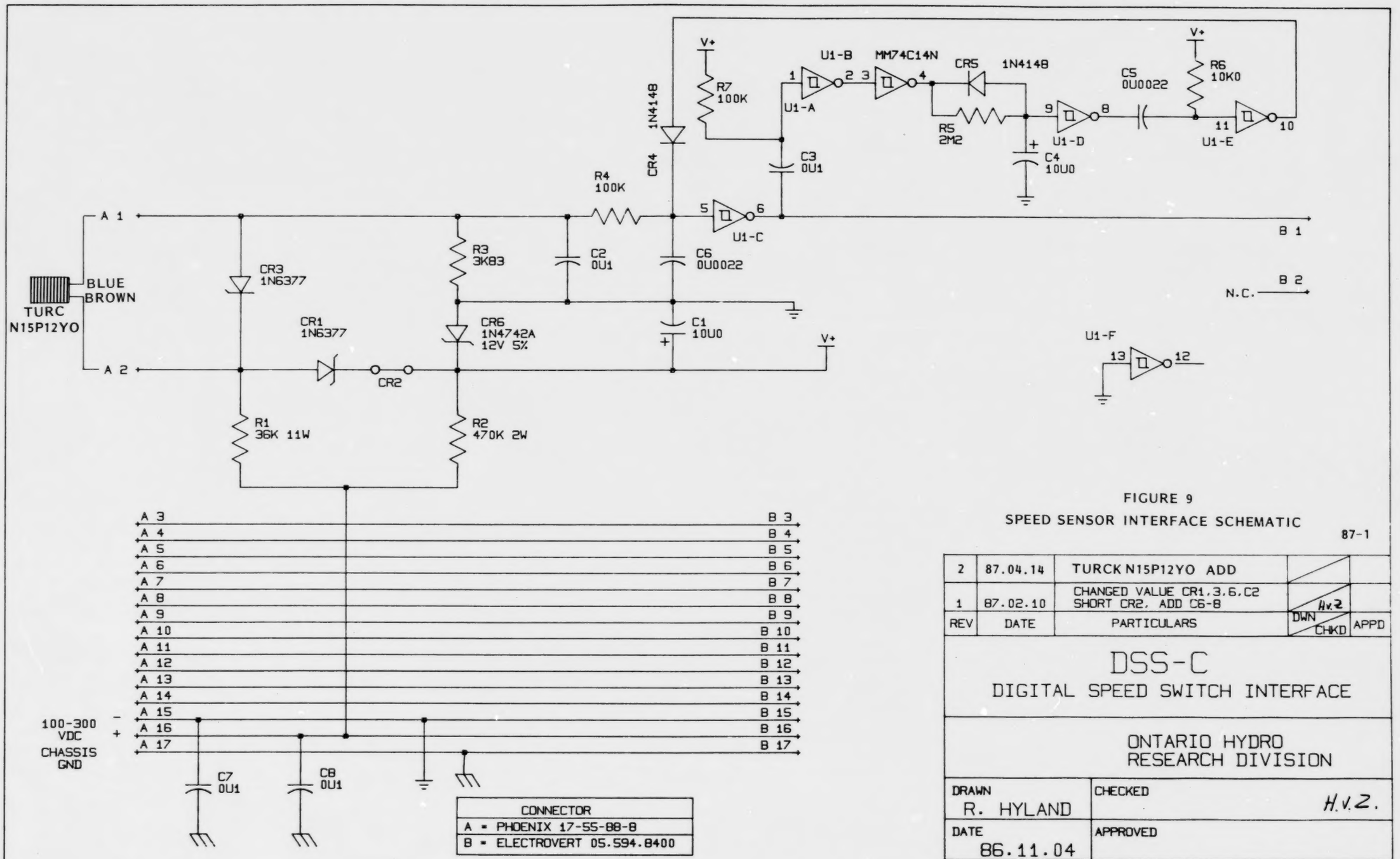


FIGURE 9

SPEED SENSOR INTERFACE SCHEMATIC

87-1

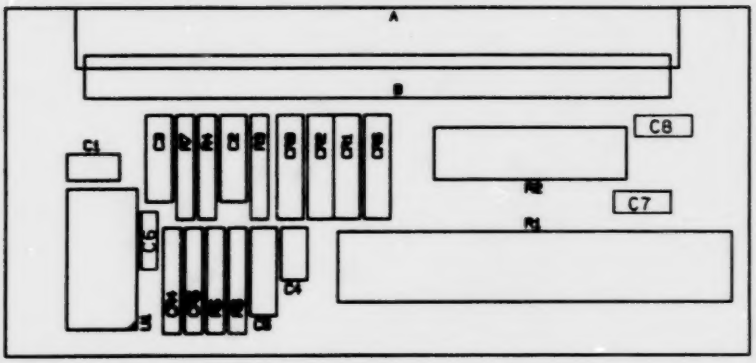
REV	DATE	PARTICULARS	DWN	CHKD	APPD
2	87.04.14	TURCK N15P12YO ADD			
1	87.02.10	CHANGED VALUE CR1,3,6,C2 SHORT CR2, ADD C6-8	H.v.Z		

DSS-C

DIGITAL SPEED SWITCH INTERFACE

ONTARIO HYDRO
RESEARCH DIVISION

DRAWN R. HYLAND	CHECKED H.V.Z.		
DATE 86.11.04	APPROVED		
SCALE	DWG. NO. 200805	RD	R 2



Note: 1. Diode CR2 is jumpered

FIGURE 10

SPEED SENSOR INTERFACE BOARD
COMPONENT LAYOUT

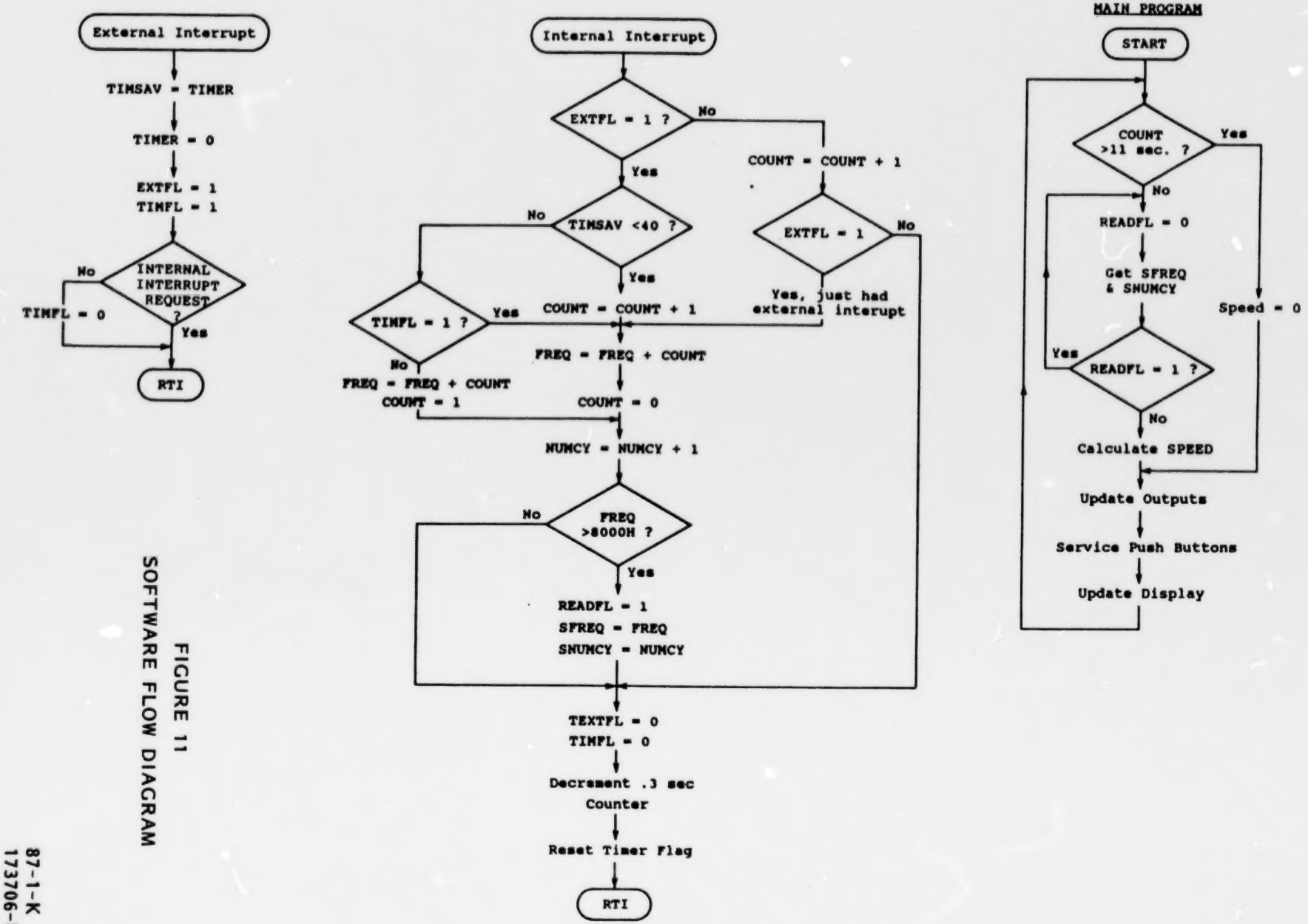


FIGURE 11
SOFTWARE FLOW DIAGRAM

87-1-K
173706-RD

APPENDIX A

Parts List DSS-1

Manufacturer	Part Number	Description	Component Ident	Qty	R
1.0 RESISTORS					
IRC	RC20-200R	200 ohm 5% 1/2 w Carbon Composition	R33,34	2	
IRC	RC20-1K	1 kohm 5% 1/2 w Carbon Composition	R37	1	
Philips	MRS25F2K00	2 kohm 1% 1/4 w Metal Film	R5	1	
Philips	MRS25F10K0	10 kohm 1% 1/4 w Metal Film	R27	1	
Dale	RH-10-18K	18 kohm 1% 10 w Wirewound	R35	1	
Philips	MRS25F24K3	24.3 kohm 1% 1/4 w Metal Film	R45	1	
Philips	MR25P30K9	30.9 kohm 1% 1/4 w Metal Film	R46	1	
Philips	MRS25F47K5	47.5 kohm 1% 1/4 w Metal Film	R2,R4,R7,R9,R11,R13, R15,R28	8	
Philips	MRS25F68K2	68.2 kohm 1% 1/4 w Metal Film	R6	1	
IRC	RC20-100K	100 kohm 5% 1/2 Carbon Composition	R36	1	
Philips	MRS25F100K	100 kohm 1% 1/4 w Metal Film	R14,R29,R41-43	5	
Philips	MRS25F150K	150 kohm 1% 1/4 w Metal Film	R10	1	
Philips	MRS25F200K	200 kohm 1% 1/4 w Metal Film	R39,40	2	
Philips	MRS25F280K	280 kohm 1% 1/4 w Metal Film	R1	1	
IRC	RC20-470K	470K ohm 5% 1/2 w Carbon Composition	R20-25	6	
Philips	MRS25F1M	1 Mohm 1% 1/4 w Metal Film	R44	1	
Philips	CR25TOL10/3.9M	3.9M ohm 10% 1/4 w Carbon Film	R8,R12	2	
Philips	CR25TOL10/6.8M	6.8M ohm 10% 1/4 w Carbon Film	R3	1	
Philips	CR25TOL10/10M	10M ohm 10% 1/4 w Carbon Film	R26	1	
Philips	MRS25F	Selected Value (nom. 39 kohm)	R47	1	
1.1 RESISTOR NETWORKS					
Dale	MSP-10A01-473G	47K ohm 2% 0.19w/R 10 Pin SIP	RN1,2	2	
2.0 CAPACITORS					
Philips	681-10229	22 pF 2% 100 V Ceramic Plate	C11,12	2	
Philips	681-70471	470 pF 2% 100 V Ceramic Plate	C23	1	
Philips	630-09472	4700 pF 10% 100 V Ceramic Plate	C25	1	
Philips	344-55103	0.01 uF 10% 400 V Polyester Film	C4,C21	2	*
Centralab	CK05BX104M	0.1 uF 20% 50 V Monolithic Ceramic	C13-15,C17-19	6	
Philips	344-25104	0.1 uF 10% 100 V Polyester Film	C6,C8-10	4	
Philips	344-61224	0.22 uF 1% 630 V Polycarbonate Film	C19,20	2	
Philips	122-56108	1 uF 20% 25 V Solid Aluminum	C16	1	
Philips	344-15105	1 uF 10% 63 V Polyester Film	C5	1	
Philips	122-56478	4.7 uF 20% 25 V Solid Aluminum	C2,C22	2	
Philips	035-56102	1000 uF 20% 25 V Electrolytic	C1	1	
Philips	630-09102	1000 pF 10% 100 V Ceramic Plate	C24	1	
3.0 SEMICONDUCTORS					
Motorola	MR814	1 A Fast Recovery Diode	CR9-13	5	
	1N4148	100 PRV Signal/Switching Silicon Diode	CR3,CR4	2	

	1N4740	10 V 10% 1 W Zener	VR4	1
	1N5232B	5.6 V 5% 1/2 W Zener	VR5	1
	2N3904	NPN Silicon Switching Transistor	Q2-Q5	4
	2N4403	PNP Silicon Switching Transistor	Q6	1
National	LM317T	5-Volt Regulator	Q1	1
Motorola	MTP2N45	N-Channel FET	Q6-9	4

4.0 INTEGRATED CIRCUITS

	74HC00	Quad 2-Input NAND	U12	1
	74HC04	Hex Inverter	U11	1
	74HC08	Quad 2-Input AND	U13	1
	74HC123	Dual Retrig Monostable Multivibrator	U3,U14	2
	74HC573	Octal Transparent Latch	U8	1
Intersil	ICM7211AMIPL	Four Digit Display Decoder/Driver	U6	1
Intersil	ICL8211CPA	Programmable Voltage Reference	U1	1
Intersil	ICL8212CPA	Programmable Voltage Reference	U2	1
Motorola	MC146805E2P	8-Bit CMOS Microprocessor	U7	1
National	NMC27C32-45	4K x 8 CMOS uV EPROM	U10	1
National	MM74C14N	Hex Schmitt Trigger Inverter	U5	1
Xicor	X2210D	64 x 4 Non-Volatile RAM	U9	1

5.0 MISCELLANEOUS

Alpha	5951	AWG 30, Solid Kynar Ins Hook-Up Wire (or equiv)		2 ft
AMP	640463-1	8 Pin DIP Socket		2
AMP	640357-1	14 Pin DIP Socket		4
AMP	640358-1	16 Pin DIP Socket		2
AMP	640359-1	18 Pin DIP Socket		1
AMP	640464-1	20 Pin DIP Socket		1
AMP	640361-1	24 Pin DIP Socket		1
AMP	640379-1	40 Pin DIP Socket		2
Belden	83004	#24 AWG Stranded Hook Up Wire (or eq.)		1 ft
C&K	E112SD1V30BE	SPDT Pushbutton	S5-6	2
C&K	8018-2	Black Pushbutton Cap		3
Cambion	704-1000-01-03-16	Miniature Switch	S2-4	3
CTS	MP010	1.00 MHz Crystal	Y1	1
General Electric	V250LA20A	250 V Metal Oxide Varistor	VR3	1
General Electric	34D5F02K	4-Digit Liquid Crystal Display	DS1	1
Hammond	1590R	Diecast Aluminum Box, Unfinished		1
Keystone	#1947	Hex Male/Female Threaded Spacer		4
Phoenix	17-57-39-4	MSTBA 17 Position Header		1
Phoenix	17-57-16-1	MSTB 17 Position Screw Terminal Block		1
Phoenix	SKS5-1-10	Marking Card		1
Phoenix	SKS5-11-20	Marking Card		1
Robinson Nugent	SBA-20-S-TG	20 Pin Socket Strip		2
Quality Circ.	DSS-A-R1	Printed Circuit Board		1
Quality Circ.	DSS-B-R1	Printed Circuit Board		1
T&B/Ansley	FSN-21A-26	26 Conductor Jumper Cable		1
	ON Dwg 200553RD	Mounting Plate		1
	2 3/8 x 1 1/4 x 0.06"	Clear Polycarbonate Sheet		1

	4-40 x 1/4	R.H. Machine Screw		6	
	2-56	Hex Nut		2	
	4-40	Hex Nut		2	
	6-32	Hex Nut		2	
	#2	Split Type Lockwasher		2	
	#4	Split Type Lockwasher		8	
	#6	Split Type Lockwasher		2	
Aromat	DSP-1E-DC24V	Miniature Power Relay	K1-4	4	
Oak	399591-LP	LoProfile Keyboard Switch (black - no engraving)	S4	1	*

APPENDIX B

ONTARIO HYDRO RESEARCH DIVISION

DSS-1 - DIGITAL SPEED SWITCH

SETUP AND TEST PROCEDURE

DOCUMENT DSS-1-TP

Test Equipment Required

ac/dc Multimeter:	3 1/2 digit, such as Beckman 3020 or equivalent
Counter/Timer:	Such as HP-5316A or equivalent
Load Resistor:	1.5 kohm 1% 1/4 W
Decade Resistance Box:	0-100 kohm
dc Variable Power Supply:	0-50 Vdc, 0.1 A
dc Power Supply:	250-300 Vdc, 0.1 A
Signal Generator:	Sine wave, greater than 2.5 Vrms output, 0-200 Hz

Note: For each unit tested the test result sheet on page 4 must be completed and shipped with the unit. If any item cannot be performed properly during any of the test procedures described, or if some item does not meet the specifications, the cause must be determined and corrective measures taken.

1. Visual Inspection

Before starting the set-up and after any installation of components during testing, inspect the PCB visually for proper soldering on all components, and ensure all components are correctly inserted (ie proper orientation of capacitors, diode, ICs etc).

2. Power Supply Setup

Ensure that the LCD and all ICs are removed from both PCBs and that switches S2 to S4 are open (up). Temporarily connect the 1.5 kohm load resistor to the output of the +5 V regulator (across VR5). Connect a decade resistance box,

set to 10 kohm, in place of R47. Apply 8.5 Vdc +/-0.5 V across VR4 (plus to cathode, minus to circuit common). Monitor the regulator output voltage across the temporary load until the voltage monitored is 5.0 Vdc +/-0.05 V. Remove power and the decade box and install a fixed 1% 1/4 Watt resistor for R47 with a value that is nearest the setting of the decade box. Re-apply power across VR4, and confirm that the regulator output is 5.0 Vdc +/-0.1 V. Remove power and temporary load and install all ICs and the LCD.

3. Current Consumption

Apply 8.5 Vdc +/-0.5 V across VR4 and confirm that the current drawn from the supply is 3.7 mA +/-0.4 mA.

4. Low Voltage Detector (U1)

Apply a variable supply set to 8.5 Vdc +/-0.5 V across VR4. Monitor the output of U1 pin 4 and decrease the supply voltage across VR4 until pin 4 of U1 goes low (=<0.2 V). The supply volts at the point U1 pin 4 switches must be within 7.4 Vdc and 7.8 Vdc.

5. +5 V Detector (U2)

Apply a variable supply set to 8.5 Vdc +/-0.5 V across VR4 and monitor the collector of Q2. Measure the regulator output voltage across VR5 while reducing the power supply voltage. The collector of Q2 must go low (=<0.2 V) when voltage across VR5 is between 4.4 Vdc and 4.8 Vdc.

6. Display Test

Apply 8.5 Vdc +/-0.5 V across VR4 and by using the "SELECTION ADVANCE" button select the "blank" display, ie leftmost digit is blanked. Press the INCREASE and DECREASE buttons simultaneously and verify that all segments on the LCD are displayed.

7. Relay Driver Test

Apply 8.5 Vdc +/-0.5 V across VR4 and connect a variable supply set to 20 Vdc to the SUPPLY terminals (-V to 15, +V to 16). Using the SELECTION ADVANCE, INCREASE and DECREASE pushbuttons, set the setpoints of selections 1 through 9 so that none are set to zero. With an oscilloscope observe the waveform at U14 pin 5. Slowly increase the input supply and confirm that the output at U14 pin 5 begins to switch from a steady +5 Vdc output to a +5 V to 0 V pulse width modulated output when the supply voltage is 25 Vdc +/-3 V. Remove all applied voltages.

8. Input/Output Circuitry

Apply an isolated 250 Vdc +/-5 V to the DSS-1 supply terminals (+Vto 16, -V to 15) and apply a 60 Hz 3 Vrms sine wave signal to the speed signal input terminals. Monitor the input frequency with a frequency counter/timer. Using the front panel controls set up the following setpoints.

Selection	Setpoint	Description
1	20	Pickup of A
2	10	Dropout of A
3	40	Pickup of B
4	30	Dropout of B
5	60	Pickup of C
6	50	Dropout of C
7	80	Pickup of D
8	70	Dropout of D
9	600	Rated speed in 1/10 Hz

Select the "blank" display to monitor the input frequency as a percentage of the rated speed setup in selection 9 above. Monitor the four relay output contacts and confirm that the output switches at the appropriate setpoints when the input frequency is adjusted from 60 Hz to 0 Hz. Verify that the actual frequency is the correct percentage of rated input (60 Hz = 100%). Note: A setpoint of 50 will cause an operation between 49.5 and 50.5%.

9. Burn-In

Apply 300 Vdc +/-5 V to the supply input and operate unit for 48 hours at ambient temperature of 25°C +/-5°. At the end of the 48 hour burn-in test apply a speed signal input and verify correct operation of the unit by exercising its setpoints, outputs and display segment tests.

DIGITAL SPEED SWITCH DSS-1

TEST RESULT SHEET

Date Tested: _____

Tested By: _____

Serial No.: _____

Ref. Step	Description	Expected	Measured	Confirmed
1	Visual inspection			_____
2	ICs & LCD out, S2-S4 open			_____
	Decade resistance (R47)		_____	
	Value of R47 installed			_____kohm
	+5 Vdc Regulator output	4.9-5.1 Vdc	_____	
3	Current consumption	3.7-4.3 mA	_____	
4	Low Voltage Detector (U1)	7.5-7.7 Vdc	_____	
5	+5 V Detector (U2)	4.5-4.7 Vdc	_____	
6	Display segment test			_____
7	Relay driver test (U14)	22-28 Vdc	_____	
8	Input/output circuitry:			
	- Output A			_____
	- Output B			_____
	- Output C			_____
	- Output D			_____
9	Burn-In (48 hours)			_____

APPENDIX C

PARTS LIST - SPEED SENSOR INTERFACE

Manufacturer	Part Number	Description	Component Ident	Qty	R
1.0 RESISTORS					
Philips	MRS25F3K83	3.83 K ohm 1% 1/4 W Metal Film	R3	1	
Philips	MRS25F10K0	10 K ohm 1% 1/4 W Metal Film	R6	1	
Dale	CW-10-36K	36 K ohm 5% 11 W Wirewound	R1	1	
Philips	MRS25F100K	100 K ohm 1% 1/4 W Metal Film	R4,R7	2	
Allen-Bradley	RC42-470K	470 K ohm 5% 2 W Carbon Composition	R2	1	
Philips	CR25T0L5/2M2	2.2 M ohm 5% 1/4 W Carbon Film	R5	1	
2.0 CAPACITORS					
Philips	36855222	0.0022 uFd 10% 400 V Polyester	C4,C6	2	
Philips	36825104	0.1 uFd 10% 100 V Polyester	C2,3	2	
Mallory	GM104MX	0.1 uFd 20% 500 V Ceramic	C7,8	2	
ITT	TAP10M35	10 uFd 20% 35 V Tantulum	C1,C4	2	
3.0 SEMICONDUCTORS					
	1N4148	100 PRV Signal/Switching Silicon Diode	CR4,5	2	
Motorola	1N4742A	12 V 5% Zener Diode	CR6	1	
Motorola	1N6377	15 V Transient Suppresion Zener (Note: Install Jumper Wire for CR2)	CR1,CR3	2	
4.0 INTEGRATED CIRCUITS					
Nat. Semi.	MM74C14	Hex Schmitt Trigger	U1	1	
5.0 MISCELLANEOUS					
Electrovert	05.594.8400	17 Position Straight Pin Header		1	
Johnson	115-0260-001	0.125 inch Polymide Spacer		3	
Phoenix	17-55-88-8	MSTBVA1.5/17G5.08 Header		1	
Phoenix	17-57-16-1	MSTB1.5/17ST5.08 Screw Term. Block		1	
Phoenix	1401213	SKS 5 Marking Label (1-10) (11-20)		1	
Quality Circuits	DSS-C	Interface Printed Circuit Board		1	
Quality Circuits	DSS-C-COVER	Circuit Board Cover		1	

APPENDIX D

SPEED SENSOR INTERFACE

SETUP AND TEST PROCEDURE

Test Equipment Required

Turck 'Multiprox' Ni-5-P12-Y0 Sensor
0-20 Vdc variable power supply
3-1/2 digit multimeter
100-300 Vdc variable power supply
Timer suitable for measuring time intervals up to 30 seconds with +/- 1 second accuracy. (eg digital wrist watch)
Mild carbon steel block (minimum 12 x 25 x 50 mm)

Sensor Test

1. Maximum Sensor Current Test - Metal Present

   Connect the variable 100-300 Vdc power supply to A15 terminal (-) and A16 (+) of connector A, noting the polarity and adjust to 300 Vdc. Connect the sensor to connector A, blue wire terminal A1, brown wire terminal A2. Hold the face of the sensor against the mild carbon steel block. Measure the voltage between terminals A1 and A15. Verify that the voltage is less than 2.4 Vdc.

2. Minimum Sensor Current Test - No Metal Present

   Adjust the dc supply to 100 Vdc. Position the sensor away from any metal (at least 100 mm). Verify that the voltage between pin A1 and A15 is greater than 9.3 Vdc.

Circuit Test

3. Inverter Trip Level Test

   Remove the sensor and replace with an adjustable 0-20 Vdc source, set to 5 Vdc, connected to terminal A1 (+) and A15 (-). Temporarily short circuit R6. Adjust dc supply to 300 Vdc. Monitor inverter U1-C output at B1 with respect to A15 or B15 and verify that the inverter output goes from HI to LO at a sense voltage of 8.5 Vdc when slowly increasing

the sensing volts from 5.0 Vdc. Set the dc supply to 100 Vdc. Verify that the inverter output goes from LO to HI at a sense voltage of 3.5 Vdc or greater when slowly decreasing the sensing voltage. Remove short circuit from R6.

4. 20-Second Timer Test

Reinstall the sensor (blue A1, brown A2). Position the sensor so the face of the sensor is against the steel block. Quickly move the sensor so it is at least 100 mm away from any metal and measure the time until the output of U1-D (pin 8 of U1) goes from HI to LO and verify that the time is 20 +10/-0 seconds.

5. Overall check at 100 Vdc and 300 Vdc

Do the following test with the dc supply voltage set at 100 Vdc and repeat with the dc supply set at 300 Vdc.

Allow for adjustable spacing between the face of the sensor and the flat surface of the steel block. Verify the output of inverter U1-C (pin B1) goes from LO to HI when the sensor spacing is adjusted frcm 100 mm to 4.0 mm. Verify that the output goes from HI to LO when the spacing is adjusted from 4.0 mm to 7.0 mm.

SPEED SENSOR INTERFACE

TEST RESULT SHEET

Date Tested: _____

Tested By: _____

Serial No.: _____

Ref. Step	Description	Expected	Measured	Confirmed
1	Sensor - against metal	< 2.4 V	_____	
2	Sensor - no metal present	> 9.3 V	_____	
3	Trip Level - HI to LO	8.5 V	_____	
	- LO to HI	3.5 V	_____	
4	20 Second Timer	20 S +10/-0	_____	
5	Overall check at:			
	- 100 Vdc - LO to HI	7 - 4 mm	_____	
	- HI to LO	4 - 7 mm	_____	
	- 300 Vdc - LO to HI	7 - 4 mm	_____	
	- HI to LO	4 - 7 mm	_____	

APPENDIX E

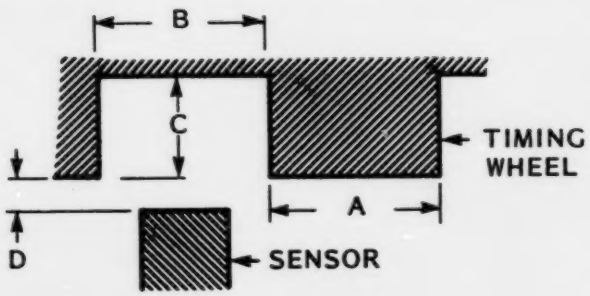
ONTARIO HYDRO RESEARCH DIVISION

SSI SPEED SENSOR INSTALLATION

SETUP AND TEST PROCEDURE

DOCUMENT SSI-TP

This appendix describes the physical requirements for a timing wheel suitable for use with of the Turck Model NI5P12YO inductive proximity sensor, for determining speed. Tests were performed to obtain the required constraints to achieve guaranteed operation. The following diagram illustrates the various constraints.



Dimension constraints:

a) $A \geq .3$ in

b) $B \geq .7$ in

c) $C \geq .6$ in

d) $0 \leq D \leq .12$ in

e) Thickness $\geq$ diameter of sensor plus any movement in thickness direction

Time constraints:

a) minimum duration of dimension A past a particular point on sensor $\geq$ 2.0 ms, at all speeds of interest.

b) minimum duration of dimension B past a particular point on sensor $\geq$ 4.7 ms, at all speeds of interest

Position Constraints

Circumferential position of trailing edges must be within ± .005 K degrees of nominal position, where K is rated speed of shaft in r.p.m.

Number of Teeth Constraint

a) Number of teeth must be $n \geq \frac{360}{a}$

where a = maximum allowable angle (in degrees) before creep detection (if required).

b) Number of teeth must be $n \geq \frac{180}{R}$ Hz

where R = rated speed in rpm

(so that frequency at rated speed $\frac{nR}{60} \geq 3$ Hz)

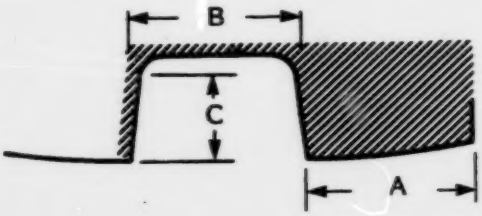
c) Number of teeth must be $n < \frac{5994}{R}$

(so that frequency at rated speed $\frac{nR}{60} \leq 99.9$ Hz)

The foregoing is an idealized configuration. In general, every practical configuration departs in at least some respect from the ideal, and therefore needs to be individually assessed for guaranteed operation. This has been done for three specific commonly used cases as described in the following. For each one, the general case constraints have been applied, making suitable adjustments as required. Note that for each case there are the timing wheel constraints as indicated, as well as the corresponding mounting constraints for the sensor, as given at the end of the Appendix. The various constraints presented have been tested and guaranteed to work. Certain violations of the constraints may be possible in some cases but further tests would be required as described in case D.

A. Milled Teeth - Radial Edges

1.



A ≥ .3 in

B ≥ .7 in

C ≥ .6 in

2. a) Travel duration of tooth past a particular point on the sensor must be $\geq$ 2 ms at highest speed of interest.

   b) Travel duration of gap past a particular point on the sensor must be $\geq$ 4.7 ms at highest speed of interest.

3. Circumferential position of trailing edges must be within +/- .005 K degrees of nominal positions, where K is rated speed of shaft in rpm.

4. Number of teeth must be $n \geq \frac{360}{a}$

   where a = maximum allowable angle (in degrees) before creep detection (if required).

5. Number of teeth must be $n \geq \frac{180}{R}$ Hz

   where R = rated speed in rpm

   (so that frequency at rated speed $\frac{nR}{60} \geq 3$ Hz)

6. Number of teeth must be $n < \frac{5994}{R}$

   (so that frequency at rated speed $\frac{nR}{60} \leq 99.9$ Hz)

7. Absolute minimum timing wheel thickness must be $t \geq .375 + p$ where p = maximum end play travel.

8. Eccentricity, mounting & bearings must be such that:

   a) Runout is small enough that sensor mount requirement #1 can be met

   b) To minimize variations in tangential speed:

   $\frac{\text{Runout}}{\text{radius}} < .01$

B. <u>Drilled Holes in Plate</u>

1. Diameter of holes: $\geq$ 1.125

2. Thickness of Metal: $\geq$ .125"

3. Spacing between hole circumferences: $\geq$ .25

4 a) Travel duration of hole past a particular point on sensor ≥ 11.25 ms at highest speed of interest.

b) Travel duration of minimal metal between holes past a particular point on the sensor ≥ 2.5 ms at highest speed of interest.

5. Requirements 2 - 6 of Case A (substitute holes for teeth)

C. Standard 1/4" Hexagonal Nuts Fastened on a Plate (mounted so flat side faces sensor)

1. Length of nut: ≥ .5"

2. Distance between nuts at their closest corners ≥ 0.5"

3. a) Travel duration of the nut face past a particular point on the sensor ≥ 2.5 ms at highest speed of interest.

b) Travel duration of the space between outside edges of adjacent nuts past a particular part on the sensor ≥ 2.5 ms at highest speed of interest.

4. Requirements 2-6, 8 of Case A (substitute nuts for teeth)

D. Cases Not Covered by A, B or C

In configurations other than A, B or C, the following tests can be performed to ensure proper operation. These tests should be performed at the highest speed of interest.

1. mount sensor such that the sensor face is .12" from metal. Using an oscilloscope verify that the interface output signal (terminal B1 with respect to B15, see Figure 9) is Hi for at least 2 ms and Lo for at least 2 ms at highest speed of interest.

2. Repeat the test with the sensor mounted as close to the metal as possible.

When these tests are complete, sensor should be left in a middle position as per Sensing Mount Requirement #5.

SENSOR MOUNTING REQUIREMENTS

1. Sensor must be mounted so that the face is never more than .12" away from face of sensed metal taking into account worst case runout (or endplay for Case B). (Runout = farthest

spacing - closest spacing)

2. Runout (Cases A & B) must be sufficiently smaller than 0.12" so that requirement (1) can be met.

3. Sensor must be mounted (Cases A & C) with the center line half way along thickness of wheel, when shaft is in middle of its axial endplay.

4. The back holding the sensor must be at least 0.5" behind face of sensor. Any other metal must be at least 2" from the face plane of the sensor.

5. The ideal mounting position is such that 1/2 (runout) = 0.60", where runout = (maximum metal to sensor spacing) - (minimum metal to sensor spacing).

Sensor Wiring

Shielded twisted pair should be used to connect the sensor to the DSS. The connection at the sensor should be as close to the sensor as practically possible. The shield should not be connected at the sensor, but connected to chassis ground at the DSS (terminal 17).

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